

NON-FLOWERING PLANTS
OF THE HIMALAYA



A coniferous forest (*Abies*) in western Himalaya

NON-FLOWERING PLANTS OF THE HIMALAYA

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Foreword

WE are living in an age of technology. Both science and technology are growing rapidly. Everything about science cannot possibly be told to a student at school or college. Consequently, the investigatory approach when adopted is the only way to arouse the curiosity of the learner and enthuse him to acquire knowledge far beyond the rigid boundaries of a curriculum. To meet this requirement, there is need to provide adequate supplementary reading material written in a manner intelligible to a student. Such material can arouse his curiosity and also quench his thirst for more knowledge.

The National Council of Educational Research and Training has undertaken the task of preparing supplementary reading material on topics which do not strictly fall within the school curriculum but which have a bearing on what the student learns at school. The present publication is one of such volumes. It is hoped that this publication will be found useful by both the students and teachers.

S. V. C. AIYA
Director

National Council of Educational
Research and Training

New Delhi

August 8, 1970

Introduction

IN presenting the second title in the series of biology background reading booklets, the choice has been a subject of never failing interest, viz , the non-flowering plants of the Himalaya

The flora of the Himalaya, both the flowering and non-flowering, in legend, lore and fact are interesting, stimulating and amazing in their impact. In fact, they have been a source of envy to those who are not inheritors of this rich domain. Our entire culture and civilization owes all its love of Nature to this rich legacy.

The flowering plants of the Himalaya, specially the flowering trees and woods have received sufficient attention, both in the hands of scientists and others. The non-flowering plants, however, deserve special focus. The range of these non-flowering plants of the Himalaya, from the one-celled algae to the manifold varieties of ferns and conifers, is perhaps the best example to impress on the young and old alike the vast diversity of biological organization.

The Himalaya have been, from time immemorial, a source of perpetual wonder, and more so because of the rich variety of non-flowering plant forms under different conditions at different levels of these large mountains. The task of describing a single type of each of these groups is by itself stupendous. That a person has attempted this difficult task and produced a booklet in a language of popular appeal, is by itself an indication of man's unending love for the beauty of the snowy peaks and towering mountains, the Himalaya.

Dr. M. A. Rau is one of our most distinguished field botanists, well known for his knowledge of the plant life of this country. His many publications in his field of specialization and, above all, his long and fruitful association with the Himalaya, make him an eminent authority on the subject-matter of the present book.

I feivently hope that this booklet will serve to stimulate both in the youth and elders of our country an abiding love for Nature's charms and create an awareness of the rich resources of the non-flowering plants both in the Himalaya and elsewhere.

T S SADASIVAN

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Preface

THIS booklet is intended to provide supplementary reading matter to the students who are already acquainted with the life-histories of the major groups of the plant kingdom through the use of 'Biology—A Textbook for Higher Secondary Schools', published by the National Council of Educational Research and Training. The Himalayan flora presents many interesting facets, and opportunity is taken in this book to highlight the main aspects of life forms and distribution of the non-flowering plants of this great mountain system. The Himalayan region is still very inadequately explored, particularly in respect of the cryptogamic plants, and its forests, river valleys and high mountain slopes offer unlimited opportunities. It is hoped that the students who read through this book will develop an active interest in the study of the non-flowering plants and take up the challenging task of unravelling the vast hidden treasures of the Himalaya. Such an effort will not only provide great enjoyment but will also prove most rewarding. There are several novelties awaiting discovery by the ardent collector.

In the preparation of this booklet, information available from published literature, more particularly the recent publications of Indian authors, has been made use of in addition to the author's own observations during his various treks in the Himalaya. A selected list of references is given to enable the teachers and the students, who may so wish, to have more detailed information on the subject. The photographs included in the booklet are all original and are in the collection of the Northern Circle of the Botanical Survey of India at Dehra Dun. The line diagrams have been redrawn and adapted from published literature and the acknowledgement of the source is made under each such illustration.

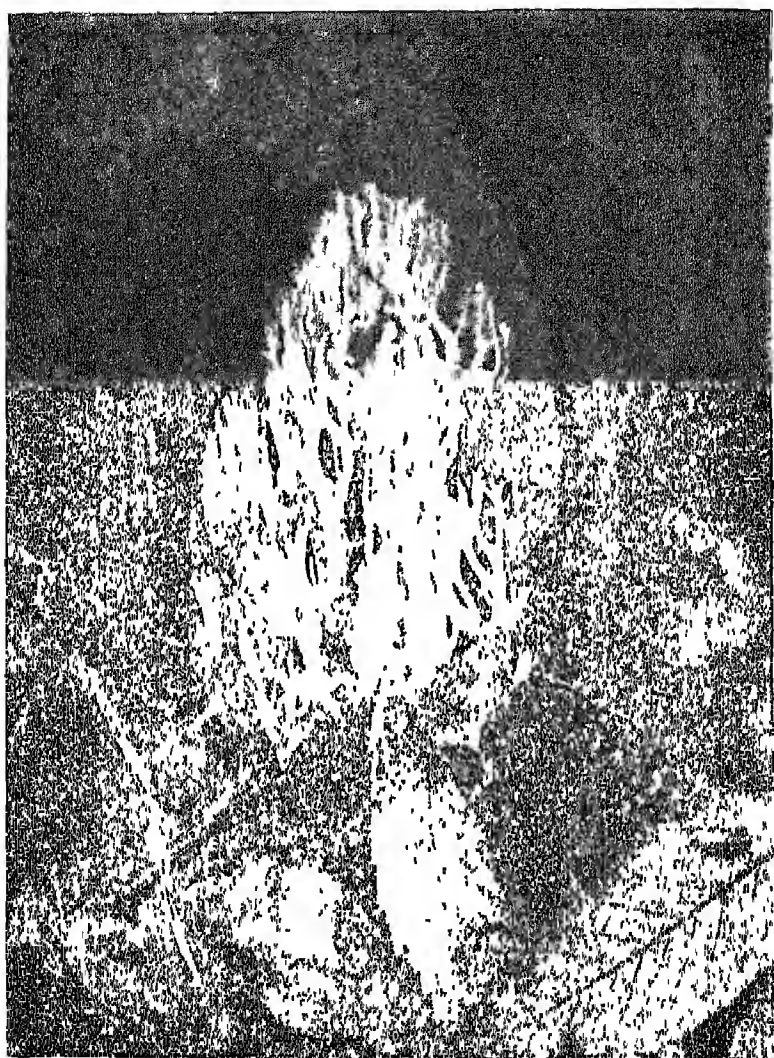
The author wishes to express his sincere gratitude to Prof. T S. Sadasivan, Chairman, and other members of the Study Group on Biology, National Council of Educational Research and Training, for many helpful suggestions. He also wishes to express his thanks to Shri G. N. Madhwal who assisted him in preparing the illustrations for the booklet.

M A RAU

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Cover : A Himalayan Agaric (Amanita Sp.)



A coral fungus (*Clavaria*) from western Himalaya

Algae

THE algae along with the fungi, lichens and bacteria constitute one of the major groups of the plant kingdom, the Thallophyta. The algae are mostly aquatic but may also be found in a variety of other habitats, in moist soil, on tree barks or as endophytes within other living organisms, both plants and animals. Some of the members found in the sea attain considerably large size and are commonly referred to as sea weeds but those occurring in fresh water are much smaller, ranging in size between the unicellular forms and the branched, filamentous or colonial types. The algae are classified into various divisions based on their cell structure and organisation, pigments, chemical nature of products of their photosynthetic activity and the methods of reproduction. Thus we have the Cyanophyta (blue-green algae), the Chlorophyta (green algae), the Charophyta (stoneworts) and the Chrysophyta (golden algae) whose representative species are met within the Himalaya. The Phaeophyta (brown algae) and the Rhodophyta (red algae) being predominantly marine do not occur here. It is likely that some of the Euglenophyta and Pyrrophyta may also occur in the Himalaya. Intensive study of aquatic formations in various sectors can alone bring to light the extent of their occurrence and distribution.

and the nature of such plant forms. In fact, the algal flora of the Himalaya is as yet insufficiently known. Only a small number of localities, considering the vastness of the territory, figure in the literature on Himalayan algae. A list of nearly two hundred fresh-water algae of India, including all those known from the Himalaya, was published by Carter in 1926. In recent years, the Japanese botanists who conducted botanical exploration in Nepal Himalaya during 1950-51, made a collection of more than 250 species of algae. Hirano has given an account of these algae.

A brief account of the algae occurring in the Himalaya is given here.

Cyanophyta

This division includes a large number of algae which are widely distributed in the world. There are non-motile, unicellular coccoid, flat colonial and filamentous forms among them. Their cells show a simple organisation. A well defined nucleus is lacking and the presence of additional yellowish, brownish or reddish pigments gives these organisms a distinct coloration. The product of photosynthetic activity is not starch but glycogen. While a detailed survey of the various Himalayan sectors has never been undertaken in respect of these algae, the available information indicates that members of the Cyanophyta exhibiting all these different types of body organisation are found here. The genus, *Chroococcus*, which has coccoid form has been found in a pond at an

altitude of 4000 m. *Aphanocapsa* in which the nearly spherical cells are arranged in a loose gelatinous mass as well as *Merismopedia* with the cells arranged in a single plane in a tabular colony are also found at altitudes up to 3000 m. A colonial type of organisation in which ellipsoidal or heart-shaped cells form groups of four in a hollow, spherical, mucilaginous, free-swimming colony is met with in the genus *Gomphosphaeria*. One of its species has been recorded from a high altitude pond in Nepal Himalaya. There are also some forms in which many spherical or elongated cells form net-like colonies. One of this group, *Microcystis*, occurs in the Himalaya.

The large majority of blue-green algae, however, show the filamentous type of organisation. The linear rows of cells (trichomes) are surrounded by a mucilaginous sheath. These filaments may be branched or unbranched. The most common filamentous members seen in the Himalaya are those belonging to the genera, *Oscillatoria* and *Phormidium*. Several species of both these genera have been found and some of them occur in the cold and icy waters of the ponds and lakes at high altitudes as well as in the warm water of the thermal springs. As for example, large patches of these blue-green algae can be seen on the rocks which are washed by the fuming water of the springs near the Himalayan shrine of Jumnotri in western Himalaya at an altitude of 3300 m. Similar occurrence of blue-green algae has also been noticed in the hot water of the 'Taptkund' at the holy shrine of Badrinath. Some of the common

blue-green algae found in the Himalaya are illustrated here (Fig. 1, A-F.).

Chlorophyta

The Chlorophyta or the Green Algae constitute the dominant algal components of many fresh-water habitats. These organisms have well differentiated nuclei and chloroplasts in their cells, the product of photosynthetic activity is starch and the chloroplasts contain characteristic bodies known as pyrenoids. The chloroplasts are of various shapes and these variations are of value in the recognition of certain genera and species. There are unicellular, colonial and filamentous forms in the Chlorophyta. Among such algae occurring in the Himalaya, there are the unicellular members of the genus *Protophycus*, several desmids, the mucilage-sheathed *Gloeocystis*, the flattened net-like forms of the Hydrodictyaceae, the colonial *Scenedesmus* (Fig. 1, M) and various filamentous representatives of the Ulotrichales and Zygnematales. Most of these algae are found in ponds, puddles and lakes at lower altitudes and only a small number of them, particularly some desmids, are seen in the cold waters of the glacial zone. *Pediastrum*, a flat colonial form of the water-net family (Hydrodictyaceae) has been found at altitudes above 3100 m. (Fig. 1, N). The well known Indian algologist, M.S. Randhawa, described a new genus of the Zygnematales, *Sirocladium*, from Kumaon Himalaya (Fig. 2, A-C). *Zygnemopsis lahulense*, another interesting alga of this order, was discovered by him in a

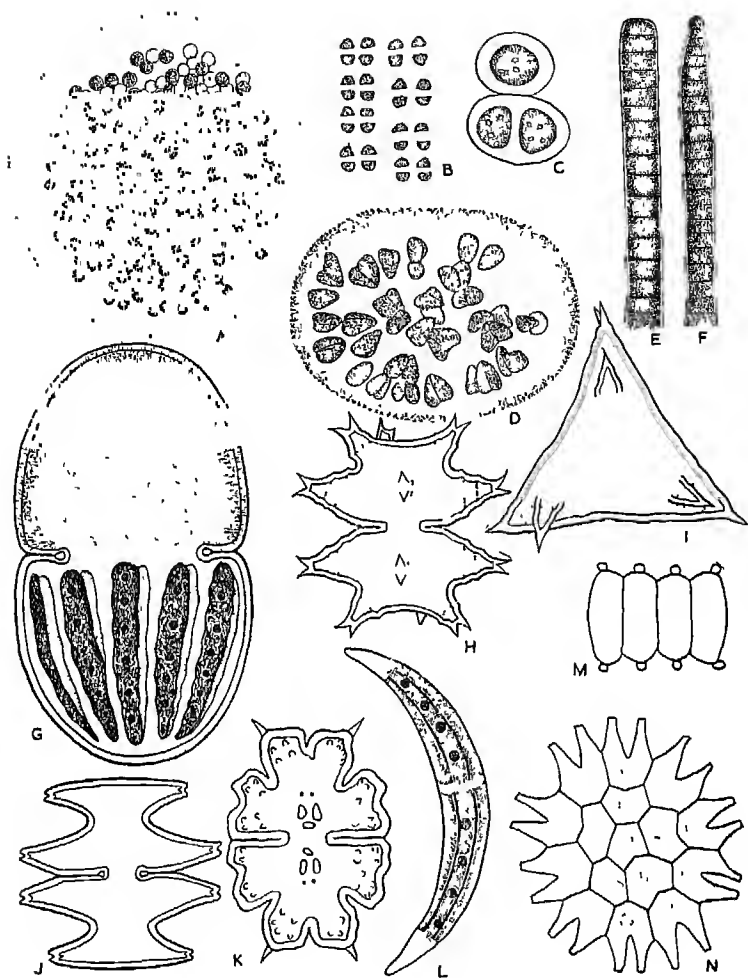


Fig 1. A-N Some common blue-green and green algae of Himalaya:
A *Microcystis flos-aquae*, B. *Merismopedia punctata*, C *Chroococcus tuigidus*, D. *Gomphosphaeria aponina*, E *Oscillatoria irrigua*, F. *Phormidium autumnale*, G. *Cosmarium javanicum*, H. & I *Staurastrum fuscigerum* (side and top views), J. *Micrasterias pinnatifida*, K *Euastrum turneri*, L *Closterium parvulum*, M. *Scenedesmus acutus*, and N *Pediatrion boryanum* —(After Hirano, 1955)
(A x 450, B x 600; C-F x 750; G-H x 500; I x 650
J x 500; K x 1000, L x 325; Mx1500; and N x 600).

fresh-water lake, Lake Sissu, in Lahul at an altitude of 3300 m. *Spirogyra* and *Zygnema*, the common representatives of this order, are frequently met with and one of them, *Zygnema terrestre*, a terrestrial alga, has been recorded from Kashmir at an altitude of 3700 m.

The genera of desmids most commonly occurring in the Himalaya, as elsewhere, are *Closterium*, *Cosmarium*, *Euastrum*, *Micrasterias* and *Staurastrum*. As is well known, the desmids constitute a unique group of unicellular and filamentous algae in which the individual cells are characteristically constricted at the middle. These desmids present an infinite variety of shapes of their cells and chloroplasts (Fig.1, G-L).

The Ulotrichales have characteristic uninucleate cells with a single laminate, parietal chloroplast. The thalli may be filamentous, branched or unbranched, sheet-like plates or solid cylinders. Species of *Ulothrix*, a common filamentous genus, thrive in the comparatively colder regions of north India. They are known from various localities in the Himalaya. One of them, *Ulothrix zonata* (Fig.2, H) has been found in a sulphur spring in Kashmir and another *U. subtilissima*, in Kumaon on rocks under dripping water. *Hormidium*, another filamentous alga, is also known from Kashmir and Kumaon, often occurring on moist clayey soil. *Schizomeris*, a genus in which the mature thallus forms a solid cylinder several cells in thickness, was collected from a waterfall in Kashmir (Fig 2, F-G). In the case of *Prasiola*, another related member, the adult thallus is an expanded sheet, one cell in thickness. The cells

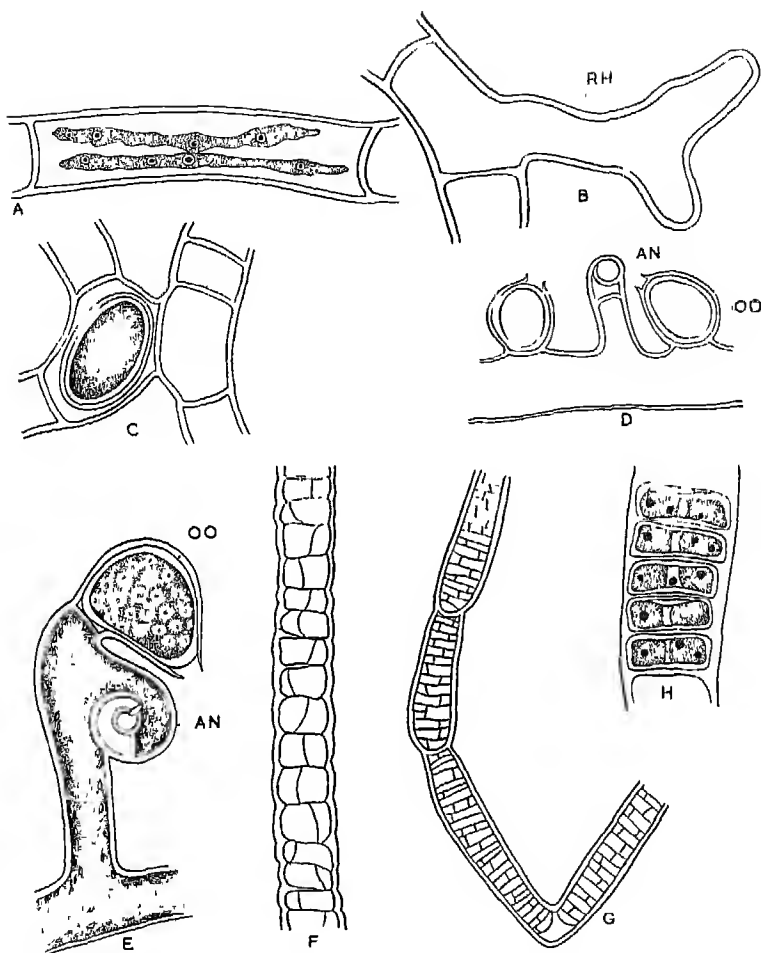


Fig. 2. A-H. A—C. *Sirocladium kumaonense*: A. Vegetative cell showing two ribbon-shaped chloroplast, B. Rhizoid, C. Conjugating filaments with ripe zygospore (after Randhawa, 1959), D. *Vaucheria sessilis*, two oogonia on either side of stalked antheridium, E. *V. terrestris*, solitary oogonium on the pedicel of antheridium (both figures redrawn from Vaucheriaceae, I.C.A.R., 1961) (rh, rhizoid; oo, oogonium; an, antheridium), F-G *Schizomeris lieblinii* septation in cells resulting in multiseriate condition, H *Ulothrix zonata* part of filament in vegetative phase (after Randhawa Proc Nat. Inst. Sci India, 14. 1948)

are characteristically grouped in quartettes. The thallus is attached to stones by a thickened stipe. This alga was collected by Randhawa from a torrential stream on the route to the Pindari Glacier in Kumaon. Prasiolas have also been found in Kashmir and Nepal. In the members of this order, reproduction takes place through the production of flagellated bodies. Both sexual and asexual methods are prevalent, the former taking place by the union of gametes in pairs and the latter through zoospores which directly develop into new plants.

Among the green algae there are some filamentous forms which exhibit various types of branching. The branches show a multinucleate condition inside and cross-partitions are lacking. These algae belong to an order known as the Siphonales. One of the characteristic representatives of this order is *Vaucheria* which is found in wet soil or in fresh and brackish waters. The alga is attached to the substratum by irregularly branched rhizoids. *Vaucheria* is peculiar among the Siphonales in possessing well differentiated sex organs, antheridia and oogonia. It differs from all other green algae in its possession of additional yellowish pigments and of oil as the assimilatory product. The production of laterally flagellated sperms is an additional character in which *Vaucheria* differs from the other green algae. The presence of some of these distinctive features has led some algologists to suggest the transfer of *Vaucheria* to the Chrysophyta. Among the *Vaucherias* occurring in the Himalaya, one of the most interesting collections was made by Randhawa of *Vaucheria terrestris* in the

Amarnath cave in Kashmir at an altitude of 3800 m. He found this alga, growing at this great altitude, in the form of yellowish green or bluish felt-like patches, on moist soil over which water was trickling from the limestone roof. This species has a wide distribution in the world being found in places as far apart as Australia and Greenland and China and Europe. Another species, *V. sessilis*, also widely distributed in the world, occurs in Kashmir and in Kumaon Himalaya. In *V. sessilis*, the sessile oogonia are generally found in pairs on either side of a stalked antheridium whereas in *V. terrestris*, the solitary oogonium is found on the pedicel of the antheridium (Fig. 2, D-E).

Charophyta

This division of algae includes the well known aquatic plants which are popularly known as the stoneworts. They generally occur gregariously in soft mud or submerged, often associated with various other plants, in still water. Some of these stoneworts are calcified and others may have a covering of mucilage. The remarkable feature about these plants is the differentiation of the plant body into a regular succession of nodes and internodes. The long internodes consist of highly elongated cylindrical, single cells whereas at the nodes, a large number of cells are present arranged in a definite pattern. At each node, a group of central cells are surrounded by peripheral cells. Short branches arise from these peripheral cells at the nodes, (Fig. 3,A). The

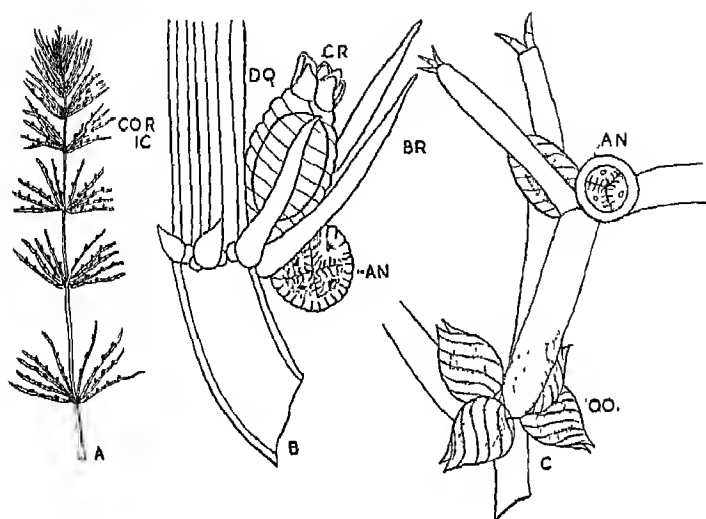


Fig. 3. A-C. A-B. *Chara zeylanica* A. Habit, B. Lowermost fertile node of branchlet with sex organs. C. *Nitella fucata*, branchlet showing antheridium and oogonium (redrawn from Charophyta, I.C.A.R., 1961) (cor. i. n., corticated internodal cell, br, bracteole, oo, oogonium with spual covering and cr, crown, an, antheridium).

internodal region, in many species of *Chara*, is ensheathed by a cortex made of vertically extending rows of cells derived by a complicated system of branches. These branches take their origin from the peripheral cells of successive nodes and grow vertically upwards or downwards and remain closely pressed to the internodal cell.

The sex organs, antheridia and oogonia are developed from the peripheral cells at the nodes. They are associated with elongated, one-celled bracteoles. The oogonium occupies a terminal position with the antheri-

dium laterally placed in *Chara* but in *Nitella*, the antheridia are in a terminal position. The antheridium has a protective covering of shield cells and inside a number of filamentous structures ultimately give rise to the sperms. The oogonium is surrounded by certain highly elongated cells which become spirally twisted around it and another set of cells forms a crown at the top (Fig.3, B-C). After fertilization, the oospore develops into a hard nut-like body which assumes a yellow, brown or black colour.

The method of reproduction is thus strikingly different in the Charophyta and this coupled with the peculiar structure of the plant body marks this as a unique group whose relations to other algae are obscure.

Some of the Charophytes are known to reach very high altitudes in the Himalaya. Representative species of the genera, *Chara*, *Nitella*, *Nitellopsis*, *Tolypella* and *Lychnothamnus* have all been recorded from the region though the total number of species is only 8 out of 65 known from other parts of the country. Of these 8 species, most of them have been recorded from the Dal Lake in Kashmir and from some localities in Kumaon. One of them, a species of *Nitella*, was found at a depth of 7 m. Our knowledge of this group in the Himalaya is, however, scanty due to inadequate exploration.

Chrysophyta

The members of this division are characterised by their yellow to golden brown colour because of the pre-

sence of the yellow-brown pigments, carotenes and xanthophylls, in greater proportion than the chlorophylls. Starch is never formed as the food reserve in these algae which usually have leucosin or oils as storage products. The diatoms (Bacillariophyceae) belonging to this division are organisms of great interest. The most striking feature about these diatoms is that their cell walls are impregnated with silicon-di-oxide. Most of them are unicellular but some colonial forms are also known. Though lacking in flagella, the diatoms exhibit characteristic jerky movements, probably, the result of interaction of the streaming of cytoplasm in relation to the structure of the two valves constituting the cell wall.

The diatoms are conspicuous components of the algal flora of both fresh-water and marine habitats. Their abundance in certain areas and the fact that the silicified empty walls (Frustules) settle at the bottom after the death of the protoplast are responsible for the building up of huge deposits of what is called diatomaceous earth. Such deposits are known from many parts of the world, these accumulations dating back to the geological ages. Diatomaceous earth finds many uses in industry.

From the Himalaya, a large number of species of diatoms have been recorded, particularly, from the aquatic formations at high altitudes. It has been noticed that while the desmids are predominant in the waters at lower altitudes, the diatoms are more numerous at higher elevations. The genera represented in the diatom flora of the Himalaya are, among others, *Navicula*,

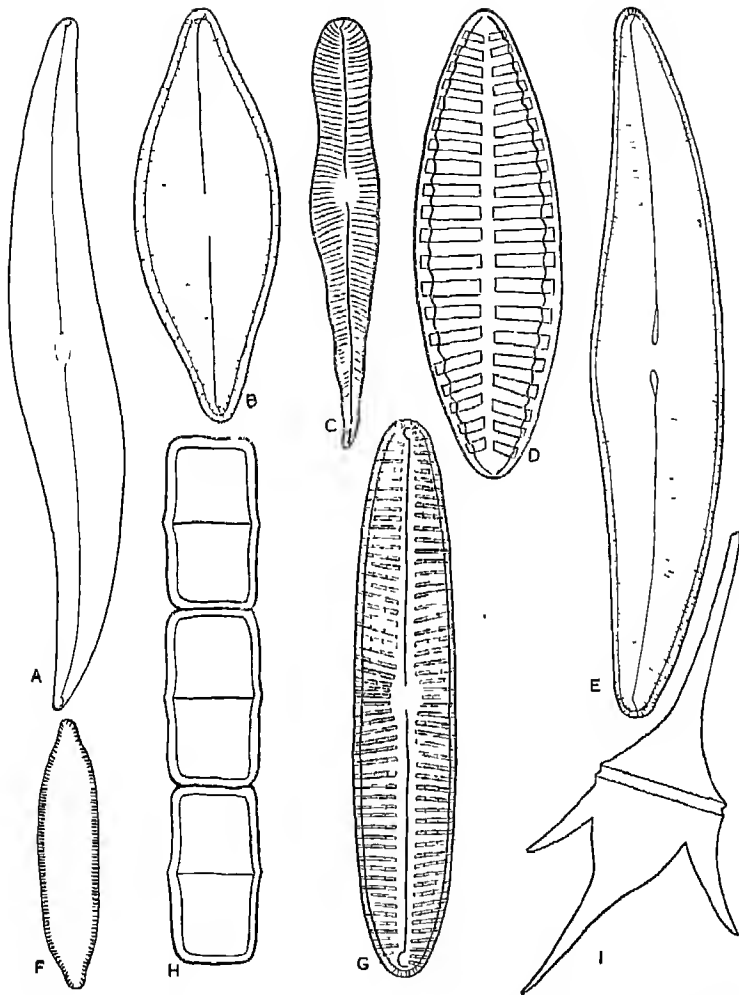


Fig 4 A-I. A-H. Some Himalayan Diatoms: A *Gyrosigma kutzingii*, B *Navicula amphibola*, C. *Gomphonema longiceps*, D *Surirella linearis*, E *Cymbella aspera*, F. *Nitzschia palea*, G. *Pinnularia viridis* and H. *Melosira varians*. I. A dinongellate —*Ceratium hirundinella* —(After Hirano, 1955)
(A-D, H x 1000, E x 500; F-G x 750)

Pinnularia, *Cymbella*, *Gomphonema*, *Nitzschia*, *Surirella* and *Melosira* (Fig. 4, A-H).

Of the remaining divisions of the algae, a dinoflagellate, *Ceratium*, of the Pyrrophyta (Fig. 4, I) is known from the Himalaya and further studies are necessary to determine the extent of distribution of representatives of the Pyrrophyta and Euglenophyta



Myxomycetes, Fungi and Lichens

THE Myxomycetes and Fungi are totally lacking in chlorophyll and hence lead a parasitic or saprophytic mode of life. The Myxomycetes, commonly known as slime molds, form a very interesting group of organisms. The vegetative phase includes a naked, amoeboid plasmodium capable of movement on the substratum which may be a leaf, a fallen twig or the tree bark. The plasmodium is also capable of ingesting organic matter from the substratum and grow in size. On account of these peculiar features, the slime molds are treated as a separate class from the fungi and are often referred to as animal-like plants or fungal animals or Mycetozoa.

The slime molds are widespread in nature and in our country had not attracted much attention till very recently. Their common occurrence is indicated by the fact that in a recent study, nearly 100 species were recorded from the Mussoorie hills in western Himalaya. Another study of a very limited area in Assam yielded more than 50 species.

The slime molds are particularly abundant in situations where warm, humid conditions prevail along with plenty of decaying vegetable matter. In general, the plasmodium creeps along the surface of the substratum and under favourable conditions of nutrition, illumina-

tion and moisture, may reach a size of several square centimeters. These plasmodia reproduce mainly through the production of spores in bodies which are usually raised on long stalks from the plasmodium. The spore-bearing bodies are of various shapes and are the most conspicuous structures of the organism (Fig. 5, A-E). The spores on being released germinate under favourable conditions producing motile, flagellated gametes which unite in pairs. The new plasmodium is organised from the zygote in due course. Among the commonly occurring genera of slime molds are *Stemonitis*, *Physarum*, and *Comatricha*, some species of all of which are found in the Himalaya.

The fungi differ from the slime molds in lacking the plasmodial organisation and in the mode of their nutrition. The fungi include three groups, the Phycomycetes, also known as algal fungi, the Ascomycetes in which the spores are produced in a sac-like body (ascus) and the Basidiomycetes which bear the spores on club-shaped structures called the basidia. There is also another class of fungi in which spores of the nature of ascospores or basidiospores are not formed at any known stage of development of the fungus. Such members are grouped together as imperfect fungi (Fungi Imperfecti or Deuteromycetes).

The plant body, in the case of fungi, is simple consisting of only single cells as in many Phycomycetes and a few Ascomycetes (e.g. the yeasts) but in all others, a mycelium of multinucleate hyphae is developed. In the case of these mycelial forms, there is often the deve-

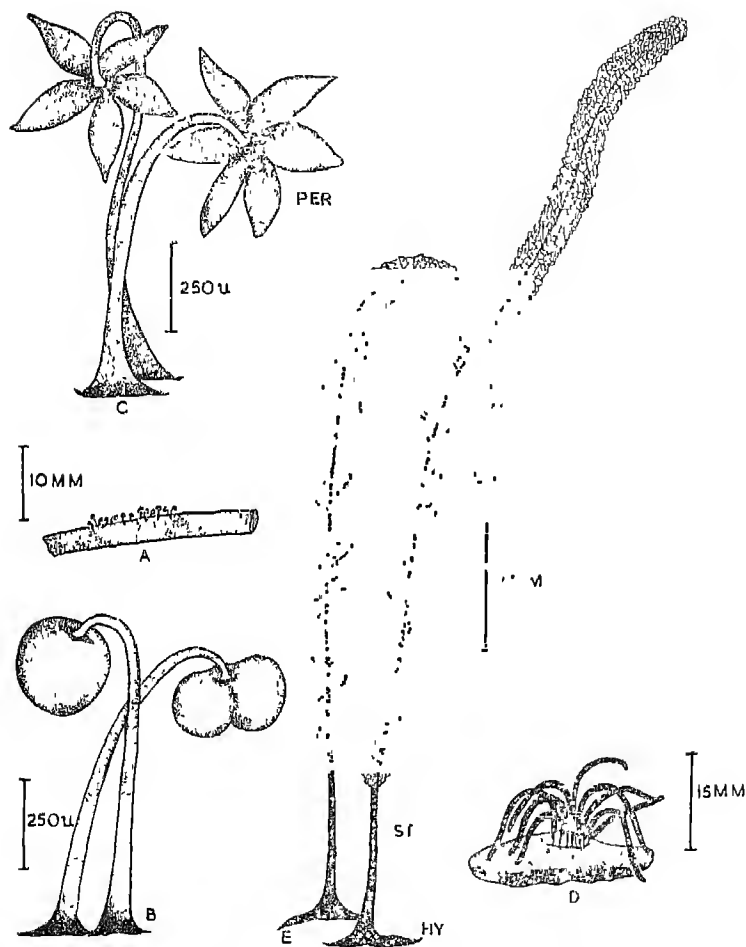


Fig. 5. A-E. Myxomycetes. A-C. *Physarum nucleatum* A Habit. B Two nodding spore-bearing bodies with their wall (peridium) intact, C. Wall dehiscent but remaining attached to stalk in a petaloid fashion. D E *Stemonitis splendens* D Habit. E. Sporangia with netlike internal structure (*hy*, hypothallus, *st*, stipe, *cap*, capillitium, the net-like interior of sporangium; *per*, peridium or sporangial wall) —(After Agnihotrudu, 1959)

lopment of elaborate 'fruiting bodies' in which the spore-bearing layers are organised. Such bodies are seen in the woody bracket fungi, mushrooms, morels, coral fungi and others. The Himalayan region with its rich flora and abundant forest litter is also the home of an extraordinary variety of fungi which are either parasitic on other living plants or thrive amidst the forest litter as saprophytes. Some of these fungi cause extensive damage to the forest trees of economic importance. As for example, the Himalayan spruce (*Picea smithiana*), one of the important coniferous trees, is known to play host to as many as fifty different species of fungi belonging to the Ascomycetes and Basidiomycetes. Likewise, the Himalayan fir (*Abies spectabilis*), another conifer, has more than thirty fungi attacking it or its timber. Most of these fungi belong to the genera, *Armillaria*, *Fomes*, *Polyporus*, *Polystictus*, *Poria* and *Trametes*. Their attack on the host tree or its timber causes various types of rotting known as the spongy rot, heart rot, brown rot, etc. Some of the coniferous trees are also attacked by the rust fungi which are found particularly on the needles. Such needle rusts (*Puccinia spp.*) are known on *Cedrus*, *Picea*, and *Pinus*. In the complex life cycle of these rusts in which the fungus spends part of its life on a different host, many herbaceous plants in the forests serve as the alternate hosts. Bagchee, a noted Indian mycologist, who has wide knowledge of the Himalayan fungi, discovered the alternate hosts for some of the rusts causing diseases of pine trees.

The downy mildews belonging to the genera, *Plasmopara* and *Peronospora* of the Phycomycetes which are well known as destructive fungi, have also been recorded on some Himalayan plants. These downy mildews with multinucleate hyphae grow as intercellular parasites within the aerial parts of the host. Some of the hyphal branches emerge out from within the host through stomatal openings and produce conidiosporeangia at the tips of branches. Apart from those fungi which live as parasites on their host, there are innumerable saprophytic members which are found on dead trunks, fallen branches, decaying vegetable litter and on soils rich in organic matter. Some of these fungi, as already stated, produce elaborate 'fruiting bodies' or fructifications.

Among the Ascomycetes, there is an interesting group of fungi which bear fructifications of the open type (apothecia). These are popularly called the cup fungi and belong to the families, Pezizaceae and Helotiaceae. The apothecia appear on decaying wood, leaves and sometimes on soil in the undergrowth of temperate forests. They are particularly common in oak forests. Other ascomycetes like *Trichoglossum* and *Geoglossum* with club-shaped, blackish fruiting bodies also occur in the Himalaya, in damp soil amidst mosses. Our knowledge of these fungi from the various sectors of the Himalaya is meagre as adequate attention has not been paid to their study in the past. Their abundance is, however, indicated by the fact that a recent study in a limited area in the Mussoorie hills of western Himalaya has brought to light more than 50 species of the Pezi-

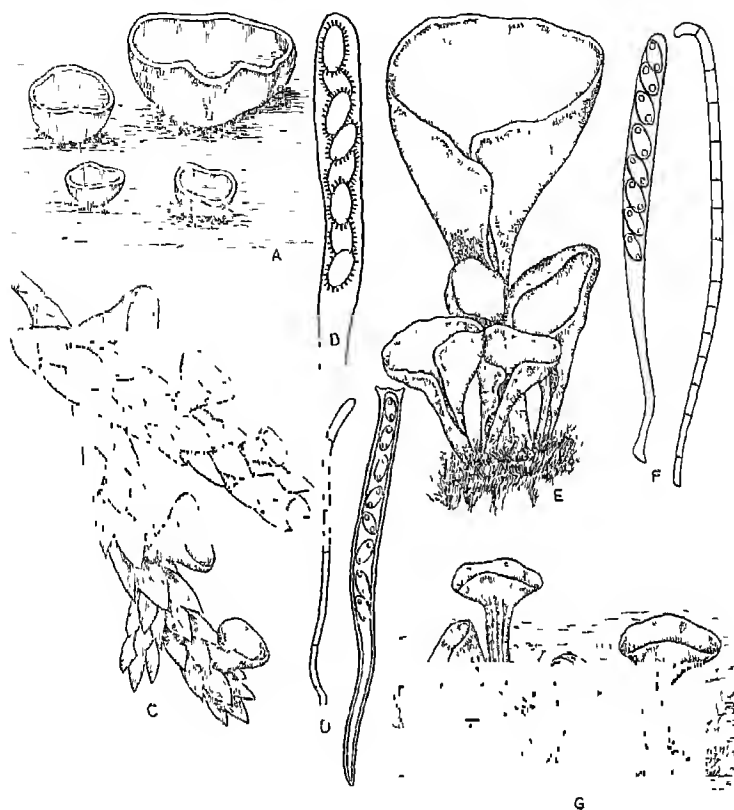


Fig. 6. A-G Pezizales · A-B *Peziza succosa* A. Habit, apothecia, B. An ascus with 8 verrucose ascospores. C-D. *Pseudopithyella minuscula* C. Habit, apothecia appearing on dead foliage of *Cupiessus* sp. D. Ascus and a paraphysis. E-F *Otidea smithii*· E. Habit, apothecia split on one side and arising from a foot-like base. F. An ascus and paraphysis. G. *Paxina macropus*. Habit with stipitate apothecia —(A-B after Thind & Batra, 1957, C-F after Thind & Pritam Singh, 1959 and G. after Thind & Waranch, 1965) (A x 1, B x 200, C x 20, D x 400; E x 0.5; F x 400, G x 0.37).

zaceae alone. Some of these fungi are illustrated here (Fig. 6,7).



Fig 7

Geoglossum sp , a member of the Helotiales with clubshaped 'fruiting body'.

It is among the Basidiomycetes, however, that the most varied development of these 'fruiting bodies' is seen. The well known woody bracket fungi are represented by many species in the Himalayan forests. These belong to the genera, *Fomes*, *Lenzites*, *Polyporus*, *Polystictus*, *Poria*, *Trametes* and others (Fig. 8-10.) Some of them are parasitic and the others are found on dead trunks or on fallen logs. In these fungi, the spore-producing

Fig. 8.

Lenzites sp., one of the pore-fungi with a corky fructification; note the radiating hymenial pores.

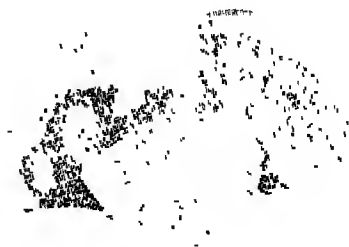




Fig 9.

A bracket fungus with stipitate
spore-producing bodies
(*Polyporus xanthopus*)

Fig. 10.

Boletus sp., fruiting
body of the fungus
which grows on the
ground.



layers (hymenia) are seen to line small tubes or pores in the 'fruiting body'. Considerable work has been done on the occurrence and distribution of the bracket fungi in the Himalaya as many of them attack valuable timber-yielding trees, conifers as well as other angiospermous trees, causing extensive damage. In these wood-rotting fungi, the hyphae attack the cell contents as well as the material of the cell walls. Depending on the nature of this attack, changes take place in the physical and chemical properties of the host tissue which are manifested in colour changes of the wood. According to these colour changes and other effects produced in the host, the fungal attacks are described as white-rot, brown-rot, heart-rot, spongy-rot, etc. The destruction of the host tissue is brought about through the secretion

of several enzymes in the hyphae of the attacking fungus. Infection may take place through wounds in living trees but more often the attack may begin on felled timber or at the time of sawing. In some cases, the living trees may be infected but the fungus remains quiescent becoming active only when the tree is felled and under favourable conditions. It then produces the 'fruiting bodies' with the eventual discharge of spores. Fungi attacking the heart wood are known as heart-rot fungi. *Fomes pini* is a common fungus of this type which causes the red-ring-rot of living trees and is responsible for serious loss to economically important coniferous species. The spruce, fir and the blue-pine in the Himalaya are all subject to attack by this fungus.

The coral-fungi (*Clavaria spp.*) form one of the most interesting and beautiful groups of fungi. This group, like most other groups of non-pathogenic fungi, has received attention only in recent years and already many species have been described from Mussoorie alone. The clavarias have erect or elaborately branched soft 'fruiting bodies' (Fig. 11, A-C). Other Basidiomycetous fungi with fleshy 'fruiting bodies' are the well known mushrooms or agarics. Some of these are edible and others poisonous. Many members of agaricaceae are found in the Himalaya. In these fungi, the spore-producing layers are arranged in radially disposed lamellae or gills. They are, therefore, known commonly as gill fungi. Some agarics are known to cause the decay of trees but others form a symbiotic mycorrhizal association with forest trees. The mycorrhizal associations in the case

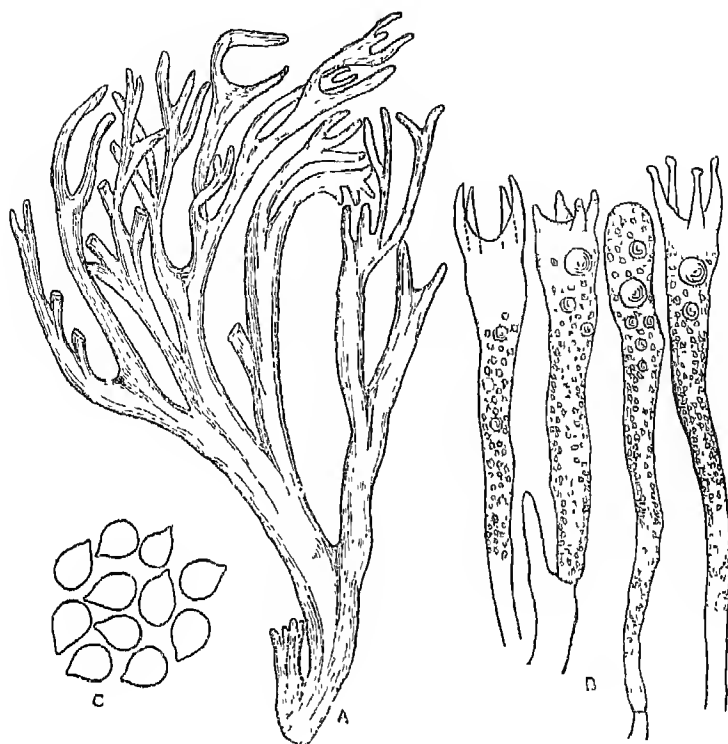


Fig. 11 A-C *Clavaria zollingeri*, one of the coral-fungi, A fructification, B. Basidia, C. Basidiospores. (after Thind and Raswan, 1958) (A x 1; B-C x 1150).

of the Himalayan conifers are now under investigation. In the case of agarics and allied fungi, the spore-producing region is at first enclosed but becomes exposed at maturity. This condition is known as hemiangiocarpic but in another group of Basidiomycetous fungi, viz., the Gasteromycetes which include the well known puff balls (*Lycoperdon* spp.), the 'fruiting bodies' or basidio-

carps remain closed even at maturity. The basidio-carps have an outer sterile portion (peridium) and an inner fertile portion (gleba). The gleba consists of numerous cavities which are lined with the spore-bearing hymenia. While in *Lycoperdon*, the peridium releases the spores through a small opening at the top, in the closely related genus, *Calvatia*, the peridium breaks into pieces and the gleba is thus exposed. These fungi have been described from Kashmir, Kulu, Dalhousie, Mussoorie and other localities in the Himalaya.

Among the other Basidiomycetous fungi found in the Himalaya, mention may be made of *Ithyphallus* of the group of stink-horn fungi and *Crucibulum* of the bird's nest group of fungi. The common earth stars (*Geastrum* spp.) with their characteristic splitting of the outer cover of the 'fruiting body' into 6-9 uniformly spread out rays (Fig. 12) also occur in the area. One of

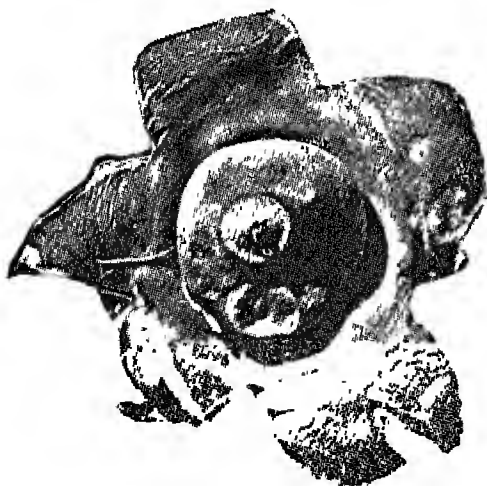


Fig. 12.
The earth star
(*Geastrum* sp.);
note the intact
inner layer of
the peridium, the
outer having split
into spreading
lobes (star-like).

these Geasters was collected at an altitude of 4000 m. along the Rohtang Pass in western Himalaya, an unusually high altitude for the occurrence of these fungi.

It is thus seen that fungi of various kinds are extremely common in the Himalaya and further exploration for them would be highly fruitful and rewarding.

Lichens

The lichens form an interesting group of plants in which two separate organisms, an alga and a fungus, are associated to live as a single individual. The fungal component of a lichen is mostly one belonging to the Ascomycetes but in a few it may be a member of the Basidiomycetes. The alga may belong to the Cyanophyta or the Chlorophyta. The lichens are widely distributed in nature and are found on soil, on bare rocks or frequently growing on tree bark, leaves etc. They are pioneers in occupying rocky habitats and by gradual disintegration of the rock surface make the way for other plants like the mosses to come in.

The lichens reproduce through the production of spores by the fungus which on germination develop into a hyphal system. If the hyphae come in contact with a suitable alga, the association begins. In the absence of such a contact with a suitable alga, the hyphae shrivel up and degenerate.

The lichens are generally recognized by their growth habits. Those closely pressed to the substratum by their flattened thallus as in the case of those growing on rocks,

are called Crustose forms. Others which have a leaf-like, lobed body attached to the substratum by separate outgrowths from the lower surface are known as Foliose lichens. The third kind is one in which the body is a branched cylindrical or ribbon-like thallus. This is the Fruticose type.

In the Himalaya, all these kinds of lichens are seen. It is an exceedingly common sight to see many fruticose and foliose lichens growing on the barks of trees (Fig. 13). At high altitudes, yellow or brownish patches of crustose lichens can be seen on bare rocks where no other plant is able to grow. *Cladonia* is a genus in-

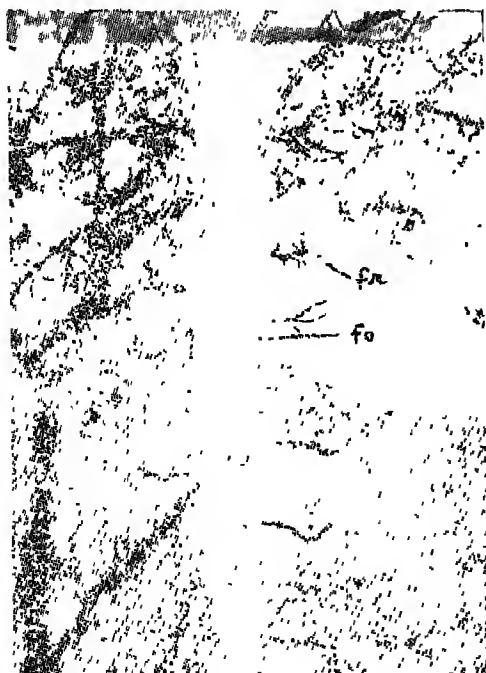


Fig. 13.
Foliose and
fruticose lichens
on the bark of
Prunus sp. (*fr*,
fruticose; *fo*,
foliose).

habiting particularly cold regions. Its species are known from altitudes above 3000 m. in the Himalaya, some of them from altitudes as high as 4600 m. The well known 'reindeer moss' which forms extensive patches in the arctic tundra is also a species of *Cladonia*. Species of *Stereocaulon*, which are mostly of the fruticose type are also common at high altitudes. One of the highest altitudes ever recorded for a lichen is 5500 m. for a species of *Gyrophora* from Nepal Himalaya. *Lobaria pulmonaria* and other species of the genus form large fleshy, greenish patches in moist situations in the forests of the temperate zone (Fig. 14). *Usnea* with long hanging thalli from tree bark is a familiar sight in most Himalayan localities. *Parmelia*, *Cetraria*, *Ramalina*,



Fig. 14.
Lobaria pulmonaria,
a foliose lichen
with greenish
fleshy thallus.

Physcia and *Anaptychia* are among the other genera of lichens frequently met with in the Himalaya.

Lichens contain various complex organic acids like, Gyrophoric acid, Salacnic acid, Usnic acid and others. Some of the extracts from lichens are useful as medicines. When treated with aqueous solutions of Potassium hydroxide, Calcium hypochlorite, Iodine (with small quantity of Potassium iodide) and freshly prepared alcoholic solution of Paraphenylenediamine, the lichens show characteristic changes in colour. The positive or negative reaction of a lichen to each one of the above chemicals is an aid in its diagnosis.



Liverworts and Mosses

THE liverworts and mosses are the two constituent classes of the Bryophyta. These represent the simplest of all land plants. The plant body is a flat thalloid structure or may be differentiated into an axis with small leafy outgrowths. Vascular tissue is lacking and the plant is fixed to the soil by rhizoids which are unicellular in the liverworts and transversely septate in the mosses. The ordinary plant in both these classes is the gametophyte, *i.e.*, the sexual generation bearing the antheridia and archegonia. These antheridia and archegonia are provided with a layer of sterile wall cells and in this respect differ from the corresponding antheridia and oogonia of the Thallophyta.

The liverworts are so named because the vegetative body in some of them is lobed and resembles the animal liver. Not all liverworts have a flat thalloid body. Some of them are leafy with a slender axis and two rows of minute leaves. The liverworts require a good deal of moisture for their growth and hence are found in the cooler and shady, moist localities. The Himalayan region is the most favourable area for their successful growth and the greatest development of the liverwort flora is seen in the altitude range of 1500 to 2500 m. At higher altitudes, particularly in the dry valleys of north-

west Himalaya, the number of liverworts present is small. Most liverworts are perennial forms with a distinct resting period during winter. Some of them found along water margin and in more favourable locations may remain fresh throughout the year; otherwise, they dry up during winter, resuming their growth only during the following rainy season.

The classification of the liverworts is based on the vegetative structure, methods of reproduction, particularly in relation to the position of sex organs on the thallus and the variation in the internal organisation of the sporophyte. Accordingly, the orders, Marchantiales, Jungermanniales and the Anthocerotales are recognized. Some of the common liverworts occurring in the Himalaya are considered here.

One of the earliest bryophytes to be recorded from the Himalaya was a member of the Marchantiales, which was named *Athalamia pinguis* by its discoverer, Falconer, in 1851 (Fig. 15, D,E). It was first described from Mussoorie but has been collected from other localities in western Himalaya during recent years. Our knowledge of the liverwort flora of the Himalaya has been gained mostly through the pioneering efforts of the late Shivaram Kashyap who published an extensive account of the group from western Himalaya. Many new species were described by him.

Marchantia is represented by four species of which the most common is *M. polymorpha*. Large patches of this thalloid liverwort are seen at high altitudes in many localities. For example, in the Rishiganga Valley near

Badrinath, at an altitude of 3600 m., extensive patches of both male and female thalli are found. Gemmae cups are also seen in abundance during the summer months. *Lunularia*, another member of the Marchantiales, with characteristic semilunar gemmae cups is more common in eastern Himalaya. *Targionia* and *Cyathodium* in which the female receptacles are enclosed by a sheath, are also found in the Himalaya. *Cyathodium tuberosum* has been recorded from moist shady places and dark caves in Kumaon up to an altitude of 2500 m. *Plagiochasma* is widely distributed—being found even in the bleak arid valleys of Ladakh. These members of the Marchantiales are all prostrate, ribbon-shaped dichotomously branched thalloid forms with a varying degree of complexity in their internal structure. On the ventral surface of the thalli are seen the scales and two types of rhizoids, one smooth and the other tuberculate. The sex organs, antheridia and archegonia, are found on the thallus itself or borne on special stalked discs. The sporophyte shows an internal differentiation into foot, seta and the spore-bearing capsule.

The common liverwort, *Riccia*, also belonging to the Marchantiales has, however, a sporophyte consisting solely of the capsule. The thallus is wedge-shaped and due to repeated dichotomous branching presents a rosette-like appearance. The sex organs are developed along the groove on the dorsal side of the thallus and the capsule also lies along the groove (Fig. 15, A-C). *Riccia discolor* is the commonest species and it is found throughout the Himalaya from the foot of the range up to an

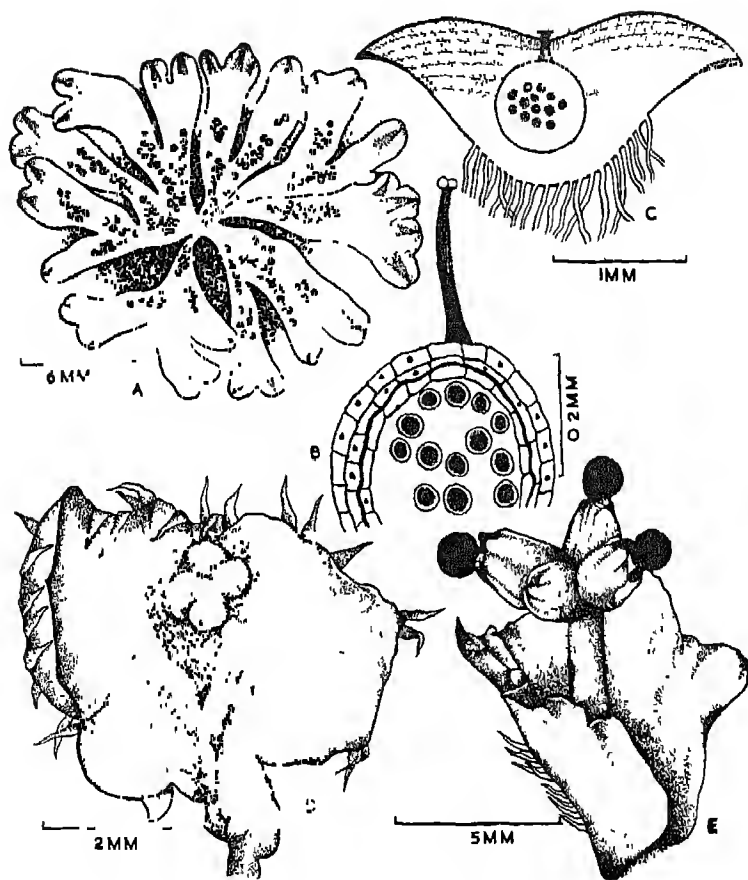


Fig. 15. A-E. A-C., *Riccia*, A-B. *R. pathankotensis*: A. Mature rosette with profuse production of sporophytes. B. Section through a young capsule. C. *R. discolor*: Tr. sec. of female thallus with sporophyte. D-E. *Athalamia pinguis*: D. Thallus with young female receptacle and antheridia, E. Thallus with mature female receptacles (A-B. after Ram Udar, 1959; C after S.K. Pande and Ram Udar, 1957 and D-E after Ram Udar, 1960).

altitude of 3000 m.

Shivaram Kashyap, the noted Indian bryologist, described a remarkable liverwort, *Aitchisoniella*, which is closely related to *Targionia*. It is found only in western Himalaya.

In contrast with the elaborate internal organisation of the thallus in the Marchantiales, the Jungermanniales have a comparatively simple vegetative structure. They are thalloid or leafy forms with little internal differentiation. Only one kind of the rhizoids, smooth type, is seen here. The sex organs are usually arranged in groups on the thallus or occasionally immersed in cavities but are never raised on stalked receptacles. *Fossombronina himalayensis* may be cited as an example for the foliose type. This plant is found on moist rocks or among grass and mosses and is particularly common in western Himalaya. Shivaram Kashyap also described another new genus from western Himalaya and named it *Sewardiella*. It is a thallose form in which the thallus is winged.

Metzgeria himalayensis and *Aneura indica* which are commonly met with in the Himalaya represent those Jungermanniales which have a membranous or fleshy thallus. The thallus is often dichotomously or pinnately branched and a distinct midrib is present. Among the Jungermanniales is also seen another type of thallus organisation in which the thallus is differentiated into an axis and leaves but there is very little internal differentiation (Fig. 16, A-B). Scales are absent. Archegonia occur in groups but are never found on stalked receptacles though the antheridia in some may be raised

on slender stalks. The sporophyte shows an internal organisation into a foot, seta and capsule. *Frullania*, *Lejeunea*, *Madotheca*, *Plagiochila* and *Lophozoa* are the common genera of the Himalaya, each being represented by several species. Species of *Lophozoa* occur at high altitudes and one of them, *Lophozoa alpestris* was found on the banks of streams in Zanskar at 4500 m. *Gymnomitrium* has been collected in Nepal Himalaya at an altitude of 5200 m

The Anthocerotales have some distinctive characters which mark them out as different from all other bryophytes. The plant body is a simple, gametophytic, thalloid structure without any internal differentiation. The cells of the thallus have a single large chloroplast which also contains a pyrenoid. On the ventral surface of the thallus numerous smooth-walled rhizoids are borne. The sex organs, antheridia and archegonia may be present on the same thallus or, as in many species of *Anthoceros*, on separate thalli. One of the characteristic features of this order is that the archegonia are embedded in the gametophyte. The antheridia are usually 2 to 4 in number and grouped together in a sunken chamber on the thallus. The sporophyte is an elongated needle-like structure and on this account *Anthoceros* is sometimes referred to as the horned liverwort. The sporophyte is a more elaborate structure than what is present in other liverworts and is differentiated into a bulbous foot, a growing region and a long capsule (Fig. 16, C-D). In the capsule, the spore-bearing zone overarches a well developed columnar tissue, the columella. The wall of

the capsule consists of chlorophyllous cells and stomata are present. The ripe capsule opens by two longitudinal valves.

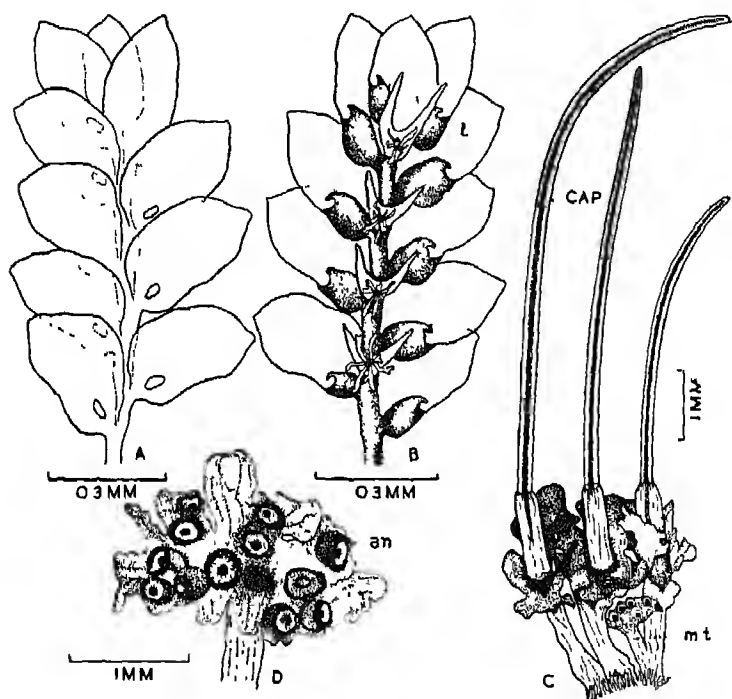


Fig. 16. A-B. *Drepanolejuenea folicola*, an epiphyllous member of the leafy Jungermanniales: part of the plant is seen in dorsal view in A and in ventral view at B. Inflated lobes of the leaf are seen on the ventral surface (l). C-D. *Anthoceros erectus*: C. A group of female and male thalli in natural position. D. A male thallus with the basal thick, stalk-like portion and expanded lamina-like part with sunken antheridia (A-B, after S.K. Pande et al, 1957; C-D, after D.C. Bharadwaj, 1960). (l, lobule; an, antheridia, mt, male thallus; cap, capsule).

Colonies of a blue-green alga, *Nostoc*, are usually associated with the thallus of *Anthoceros*.

Five species of *Anthoceros* are known from the Himalaya. These are mostly distributed in the altitude range of 1000 to 2500 m. *Notothylas*, another genus of this order which differs from *Anthoceros* in possessing a short conical capsule and in the absence of stomata in the capsular wall, has also a species occurring in the Himalaya, particularly in the outer ranges of western Himalaya.

Mosses

The mosses are leafy gametophytic structures which are found growing gregariously in thick patches in a variety of habitat—on rocks, on tree barks, on leaves, generally in moist shady localities. The slender leaf-bearing axes (gametophores) arise from a trailing filamentous body known as the protonema which dies when the erect branches are well established. These erect branches are attached to the substratum by slender, septate rhizoids. The minute leaves are arranged in a spiral fashion on the axis. The sex organs, antheridia and archegonia, are borne in clumps at the tips of these leafy branches. After fertilization, the sporophyte develops but remains attached to the leafy axis. The sporophyte consists of the foot which lies embedded at the apex of the gametophore, an elongated seta and the capsule. The capsule in mosses shows an elaborate internal differentiation with a sterile columnar tissue, a

photosynthetic aerated tissue, the sporogenous zone and the lid with a complicated structure. The opening of the lid releases the spores.

In recent years considerable work has been done on the Himalayan mosses and many interesting forms have been described from these heights. Chopra and his associates have investigated the mosses of western Himalaya and Gangulee has given an illustrated account of the mosses of eastern India. As in the case of liverworts, the mosses also require adequate moisture during their growing season and hence the most luxuriant growth of these plants is seen at altitudes between 1000 and 2500 m. Their number gradually decreases with increasing altitude correlated with the diminishing rainfall, though there is the record of a moss having been collected at an altitude as high as nearly 6000 m. in Nepal. In oak forests one can see the mosses at their best. The trees are covered densely with them, many different species often occurring together. Epiphyllous mosses are also common and this condition is more vividly seen in the east Himalayan forests.

The mosses are divided into three orders based on their vegetative structure as well as on the nature of the stalk which raises the sporophyte above the gametophyte. The Sphagnales or the bogmosses are well known for their role in the formation of peat. Extensive formations of peat are known in Europe and North America. In the Himalaya, *Sphagnum* is known to occur in a few localities but it is nowhere abundant and characteristic peat bogs are absent. *Sphagnum* generally grows in

habitats like ponds, swamps and other moist places where the acid content of the water or soil is high. The dead tissues of several generations of these plants, in course of time, develop into peat. Peat is valued as a fuel and as a packing material. It is also used for improving the water retaining capacity of the soil. *Sphagnum* has been recorded from Sikkim at altitudes of 3000 m. It is rather rare in western Himalaya where it has been collected occasionally from localities of about the same altitude in Chamba, Kinnaur and Kumaon (Fig. 17, A-B):

The Andraeales or what are commonly known as granite mosses, though resembling the Sphagnales in the nature of the stalk of the sporophyte, exhibit many characters seen in the true mosses (Bryales). The capsule in *Andraea* is, however, strikingly different from both the above orders. The capsule of *Andraea* characteristically dehisces into four valves. This genus is restricted to cold regions and high mountains and some species are known from Sikkim Himalaya. Very recently, a species of *Andraea*, was found for the first time in north Garhwal in west Himalaya.

The large majority of mosses belong to the order, Bryales or what are known as the true mosses. In these, the protonemata are always filamentous, producing a number of gametophores. The sporophytes have an elongated seta which raises the capsules above the gametophyte in contrast to the condition in *Sphagnum* and *Andraea* where it is part of the gametophytic tissue which supports the capsule. In the true mosses, the spore-

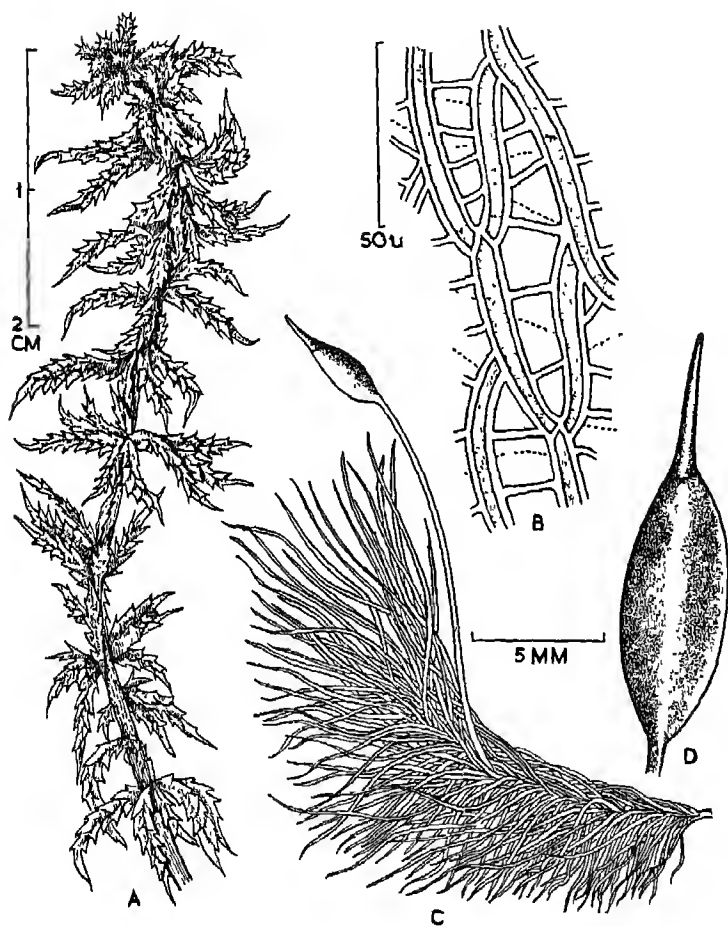


Fig 17. A-B. *Sphagnum squarrosum*. A. Habit with leafy short branches in whorls at nodes, B. Cells from dorsal face of branch leaf. C-D. *Dicranum himalayanum*. C. Habit, D. Capsule (A-B, after Wadhwa and Vohra, 1966; C-D, after Gangulee, 1960)

bearing region in the capsule does not overarch the columella as in *Andraea*. The mature capsules of true mosses have an elaborately organised cap or operculum which opens through the action of the peristomial teeth. Several genera of the Bryales are found in the Himalaya, among them may be mentioned *Barbula*, *Brachythecium*, *Bryum*, *Fissidens*, *Grimmia*, *Leucobryum*, *Philonotis*, *Pogonatum* and *Racomitrium*. One of the Mniums was collected at 4900 m. in Nepal and a species of *Angstroemia* at nearly 6000 m. These are some of the highest altitudes known for the occurrence of mosses. *Dicranum himalayanum* (Fig. 17, C-D), *Didymodon microstomus*, and *Webera carneoides* also occur at altitudes above 4000 m. One of the prettiest of these high altitude mosses, *Philonotis speciosa*, with shining greenish yellow gametophores and finely attenuated leaves, is found in Zanskar at 4500 m.



Ferns and Their Allies

THE ferns, club-mosses (*Lycopodium*), horse-tails (*Equisetum*) and other related groups of plants belong to the division, Pteridophyta of the plant kingdom. In the previous chapter, it has been stated that the Bryophytes are lacking in a vascular tissue (Xylem and Phloem) and that their plant bodies represent the gametophytic or sexual generation. Two very significant changes are noticed when we consider the pteridophytes. The plants have a well developed vascular tissue and they belong to the spore-producing generation. The spores on germination give rise to a separate, thalloid or tuberous, aerial or subterranean gametophyte on which are formed the sex organs. In the life-cycle of a pteridophyte, therefore, there are two distinct plant bodies—the dominant sporophyte with stem, roots and leaves and bearing sporangia, and the free living, small thalloid or tuberous gametophyte. The gametophyte may be green and photosynthetic or may remain underground in association with a fungus. It bears the antheridia and archegonia. The alternation of the diploid and haploid generations is thus clearly demonstrated in the life-cycle of a pteridophyte. The ferns are the most abundant and prominent members of the present day pteridophytic flora. In the ancient past,

300 to 400 million years ago, giant lycopods and horse-tails were dominant in the world flora but these groups are now represented only by a small number of herbaceous members.

In the Himalaya, some species of *Lycopodium* are met with. These club-mosses, as they are popularly known, may have a creeping habit, trailing along in the forest undergrowth as in *Lycopodium cernuum* or they may be epiphytic growing on tree trunks. *L. setaceum* is frequently seen on oak trees. The sporangia are found in the axils of leaves (Fig. 18) The sporangia may often



Figl 18.
Lycopodium setaceum:
Habit with sporangia
in the axils of leaves.

be aggregated in the axils of reduced leaves forming compact strobili at the ends of branches (Fig. 19). *Lycopodium* is a homosporous form because all the sporangia bear only one kind of spores. The gametophytes developing from the spores may have a photosynthetic tissue or may lead a saprophytic life with the association of a mycorrhizal fungus.



Fig 19.
Lycopodium squarrosum
Habit with drooping
strobili

Selaginella has several species occurring in the Himalaya. They are generally seen on rocks and on slopes in shade, associated with mosses and ferns. The stem is usually prostrate with short erect branches (Fig. 20). The leaves are in four series on the axis, two consisting of larger leaves and the other two of smaller size. *Selaginella* is a heterosporous member and bears sporangia of two kinds. These micro and macrosporangia are found in short strobili at the ends of fertile branches.

Psilotum is a peculiar pteridophyte with a rootless,

Fig 20
Selaginella involvens
(from a Kumaon
specimen)



dichotomously branched plant body (Fig. 21). The erect shoots arise from a rhizome and are usually found

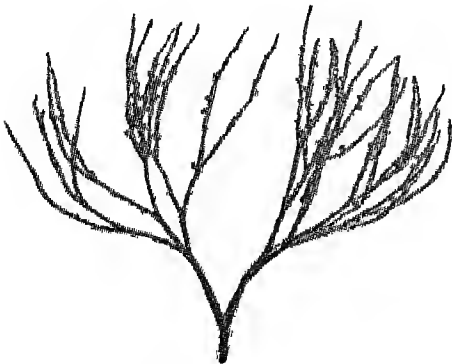


Fig 21.
Psilotum nudum: Part of
dichotomously branched
shoot with sporangia
(from a specimen from
Garhwal Himalaya).

in clumps of a dark green shade. The rhizome is associated with a mycorrhizal fungus. The aerial shoots bear no regular leaves but only scale-like structures. The sporangia are borne in groups of three and the peculiarity is that these sporangia are fused with one another. *Psilotum nudum*, a species widespread in tropical and sub-tropical regions of the world, is also seen in the Himalayan outer ranges in a few localities.

The genus, *Equisetum* (horse-tails) represents the modern descendants of a very ancient group of plants which dominated the vegetation of the world during the Carboniferous period of the Palaeozoic Era. There were many kinds of horse-tails, some of them giants, and they formed a very conspicuous element of the flora of those times. Of this remarkable group of plants, only the genus, *Equisetum* is seen in the flora at present. The plant body here consists of the horizontal, branched, perennial rhizome and erect, aerial shoots which are repeatedly branched. The rhizome and the aerial branches are prominently differentiated into nodes and internodes. The internodal surface shows a ribbed appearance. At the nodes, reduced leaves are present which alternate with the ribs of corresponding internode they subtend. The aerial branches are differentiated into fertile and sterile kinds. The former bears the sporangia, aggregated in club-shaped strobili at their tips. The spores produced in these sporangia are all of one kind (homosporous).

The spores on germination form the gametophytes which are found on soil in moist places. They are

either circular or irregular in shape. On the upper surface of this disc-like body, a number of green lobes are seen. The disc may be 1 to 2 cm wide and in due course develops the sex organs. The gametophytes of *Equisetum* are long lived.

In the Himalaya, the species of *Equisetum* are widely distributed, particularly, along stream banks. *Equisetum arvense* has been found at altitudes as high as 3600 m. (Fig. 22). *E. diffusum* and *E. debile* are common at lower altitudes.

Fig. 22.

a) *Equisetum arvense*:
Part of fertile
branch with strobilus
(from a specimen
from Kumaon, alt.
3600 m), b) *E.*
diffusum (from
Tehri-Garhwal).



The dominant members of the Pteridophyta are, however, the ferns which are all included under the class, Filicopsida. The Filicopsida includes two distinct groups, the eusporangiate and the leptosporangiate ferns. In the former, the sporangium originates from a group of cells and the sporangial wall is more than one cell in thickness. The leptosporangiate ferns, on the other hand, have a sporangium originating from a single cell and the wall is only one cell in thickness. Among the eusporangiate ferns, two genera of the Ophioglossales are found in the Himalaya. One of these, *Ophioglossum*, which includes the familiar adder's tongue, has two species represented in the Himalayan region. These are small, herbaceous plants with a single undivided, linear or oval leaf and an elongated simple spike arising from a point near the attachment of the leaf blade to its petiole. *Ophioglossum vulgatum*, the commonest species in India, is also found in various localities of both eastern and western Himalaya, up to an altitude of 2000 m. The other species, *O. polyphyllum*, is known from a much higher altitude in northwestern Himalaya.

Botrychium, the other genus of the Ophioglossales, found in the Himalaya has three species. One of these, *Botrychium lunaria*, commonly known as the moonwort, occurs on grassy slopes at high altitudes. The two other species, *B. virginianum* and *B. ternatum* (Fig. 23), with large branched spikes are found at lower altitudes. The sporangia in all these members open by transverse slits.

The leptosporangiate ferns constitute the largest

Fig 23
Botrychium ternatum
(a Garhwal specimen)



group among the Pteridophyta. While the large majority of them are terrestrial in habit and produce uniform kind of spores (homosporous), a small specialised group, the Hydropteridales, is aquatic and its members bear two kinds of spores (heterosporous). Several families are recognized among the leptosporangiate, homosporous ferns. The nature and position of the annulus (a group of thickened cells in the sporangial wall), the mode of opening of the sporangium and the position of the sori

(groups of sporangia) on the leaf are all aids in the recognition of these families.

The Osmundaceae include the royal fern, *Osmunda regalis*. This elegant fern is seen throughout the Himalaya at altitudes around 2000 m. At higher altitudes, the large fern, *O. claytoniana* is found on slopes and the edge of birch forests. This fern has thick, dark brown, sori-bearing pinnae interspersed with sterile greenish pinnae (Fig. 24). In these Osmundaceous ferns the sporangium has only a rudimentary annulus consisting of a few thickened cells at the apex and opens by a short slit.

The Gleicheniaceae are characterised by the presence of a complete transverse, medial annulus in the sporangium which opens by a longitudinal slit. The Gleichenias are common on slopes in Sikkim and other east Himalayan localities but are comparatively rare in west Himalaya.

The Hymenophyllaceae include both epiphytic and terrestrial members. The sporangium here has a complete, obliquely placed annulus. Some of the epiphytic members are the well known filmy ferns so conspicuous in the moist forests. In the Himalaya, representative species of the family are met with in Sikkim and other eastern localities as well as in Mussoorie, Simla and other places in western Himalaya.

The Pteridaceae are characteristic terrestrial ferns. Some of them attain large sizes. The sori are typically marginal, often protected by a covering (indusium) and the sporangia have an interrupted, oblique annulus.

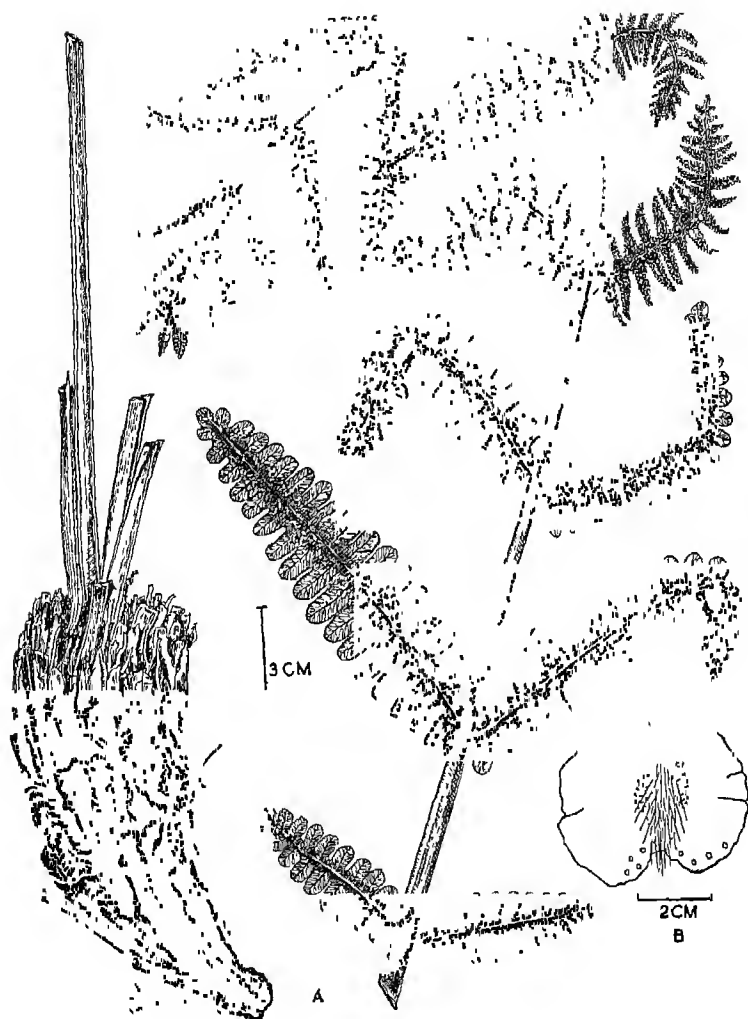


Fig. 24. *Osmunda claytoniana*. A. Habit with the stout rhizome and frond with dimorphic pinnae, B. Gametophyte (A. original drawn from a specimen collected in Tehri-Garhwal Himalaya, B. after Stokey and Atkinson, *Phytomorphology*, 6, 1956.)

The sporangium opens by a transverse slit. Several genera of the family are found in the Himalaya. These include the familiar, maiden hair ferns (*Adiantum spp.*). *Adiantum pedatum*, often seen hanging from rock ledges in western Himalaya, is a particularly beautiful fern. One of the most attractive ferns of this family is *Onychium*. Here the leaves are divided into a number of fine lobes and the sori-bearing tips often assume a golden colour.

The silver ferns (*Aleuritopteris farinosa*) so named because of the silvery white bloom on the under surface of the leaf are common in many localities. An interesting fern in which the sori-bearing leaf is separate from the vegetative one (dimorphic), *Cryptogramme crispa* (Fig. 25) is found at high altitudes. The bracken fern, *Pteridium aquilinum* and species of *Pteris* also occur in the Himalaya.

An aquatic fern, *Ceratopteris thalictroides*, with finely divided leaves is occasionally found in ponds and stagnant pools in the outer ranges and at the foot of the mountain. This fern belongs to the Parkeriaceae. Some epiphytic ferns of the Davalliaceae are also frequently seen in the Himalayan forests of the temperate zone.

The Aspidiaceae constitute one of the largest families of ferns. These ferns bear their sori on the dorsal surface, rarely in a marginal position. The sporangium has a longitudinally disposed annulus. Many well known genera of this family occur in the Himalaya. Some of these ferns are epiphytic but most are terrestrial. Species

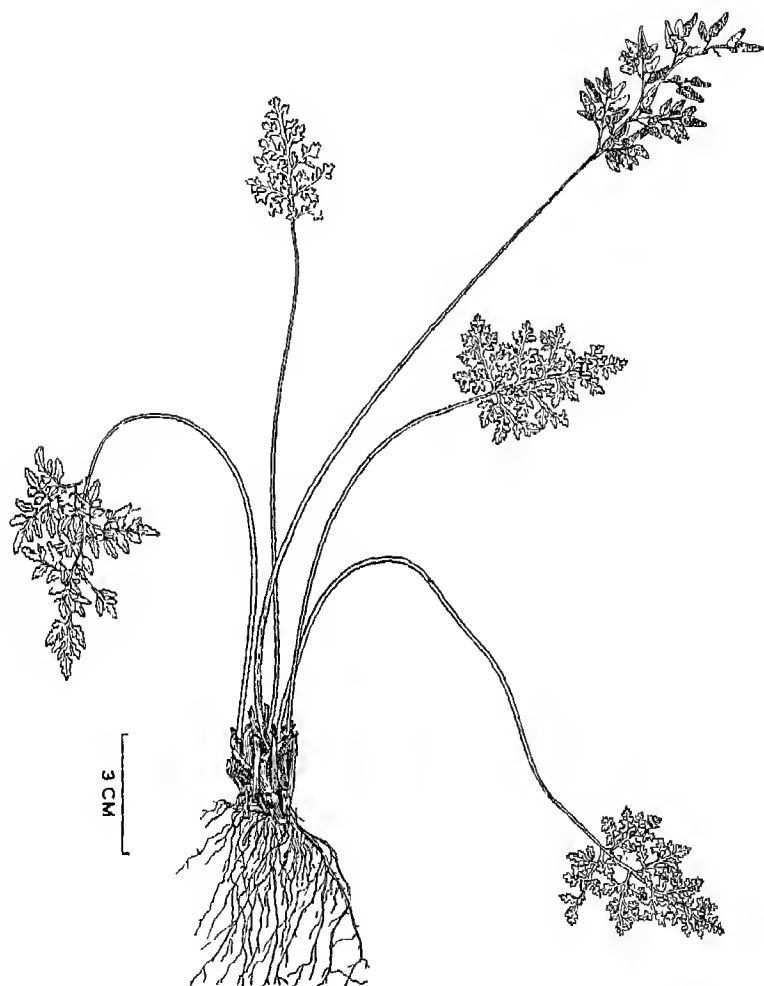


Fig. 25. *Cryptogramme crarpa*, a dimorphic fern (original dr from a specimen collected in Garhwal).

of *Polystichum* are hardy ferns and are abundant in the region. The stiff, shining leaflets of some *Polystichums* are easily recognized (Fig. 26). *Dryopteris* is another



Fig. 26.
Polystichum
acanthophyllum
(from a Garhwal
specimen)

genus which is very well represented in the Himalaya.

In the oak-Rhododendron forests one often comes across a large fern with pale green fronds. This fern, *Woodwardia radicans* of the Blechnaceae, with large bipinnate fronds (Fig. 27) has a wide distribution throughout the Himalaya and elsewhere in the world. One of the characteristic features of this fern is the presence of

numerous sori, deeply impressed on the thick frond. The fern is usually found in shade in forests of the lower temperate zone but may also occur on calcareous soil in moist ravines.

Fig 27

Woodwardia radicans
(photograph of a
specimen growing in
an oak-Rhodo-
dendron forest in
eastern Kumaon).



The Asplenoid ferns are mostly small ferns of terrestrial habitats, particularly common in rock crevices at high altitudes. *Asplenium viride*, *A. septentrionale* and others have been found at altitudes above 4000 m. Some of these occurring at very high altitudes are extremely reduced in size and grow in sheltered situations like rock crevices and under rock ledges. The sori are characteristically elongate. *A. planicaule* and *A. alternans* are very

common at lower altitudes where they occur as epiphytes or on rocks (Fig. 28). *A. nidus* is a common epiphyte of eastern Himalaya at lower altitudes. The plants form a sort of 'nest' on the branches of trees.

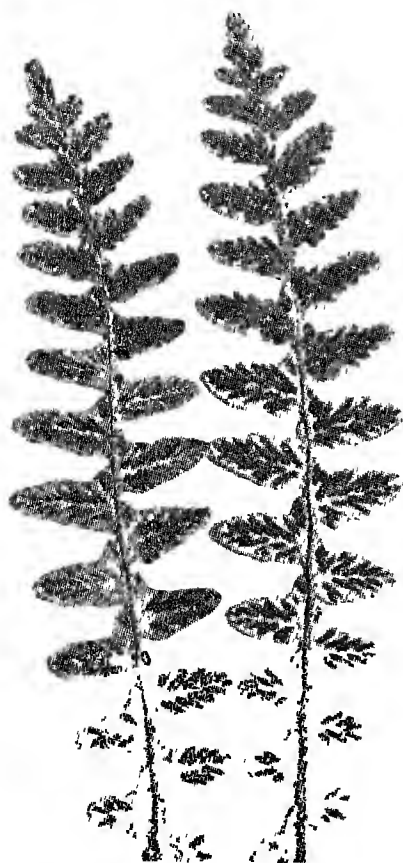


Fig. 28.

Asplenium alternans (from a specimen collected in Tehri-Garhwal).

The Polypodiaceae represent a highly specialised group of epiphytic ferns. Its members usually have

simple, linear leaves. The rounded sori (in some elongated) are distributed all over the surface along the veins (Fig. 29,30). The sori have no covering and the

Fig 29.

Arthromeris wallichiana, a Polypodiaceous fern with rounded, unprotected sori (specimen from eastern Kumaon)

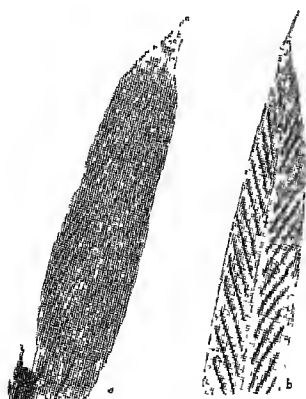


Fig 30.

- a) *Pyrosia flocculosa* with thick frond and numerous small sori.
- b) *Loxogramme involuta* with elongated unprotected sori

sporangium has a longitudinal annulus. The Polypodiaceous ferns present several interesting features in

their adaptation to the environment. Those growing in favourable situations with adequate moisture have very thin and membranous leaves and at the other extreme are those found in drier habitat which have very thick and sometimes leathery leaves. *Microsorium membranaceum* and *Pyrrosia flocculosa* are examples of these two extreme kinds. *Drynaria* is a genus of large epiphytic ferns with stout, fleshy creeping rhizomes. The leaves are of two kinds, one is sessile, short and shallowly lobed and the other, normal, stalked and pinnatisect (Fig. 31). The former kind of leaves serves for the collection of organic

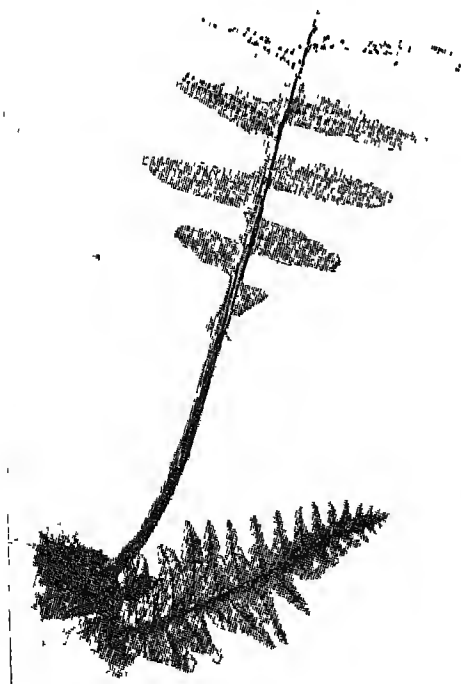


Fig 31.

Drynaria mollis: an epiphytic fern with two kinds of leaves, the shorter sessile leaf with shallow lobes (collecting leaf) and the larger normal, spore-bearing leaf.

matter or humus. *D. mollis* is a very characteristic fern on the bark of oaks, cedars and other trees in forests.

The heterosporous leptosporangiate ferns included under the Hydropteridales are aquatic in habit, either floating in water or rooted in mud. The genus, *Marsilea* with its characteristic cruciform arrangement of pinnae in its leaf has two species, *M. oblonga* and *M. minuta* in the Himalaya (Fig. 32). The sori are borne in

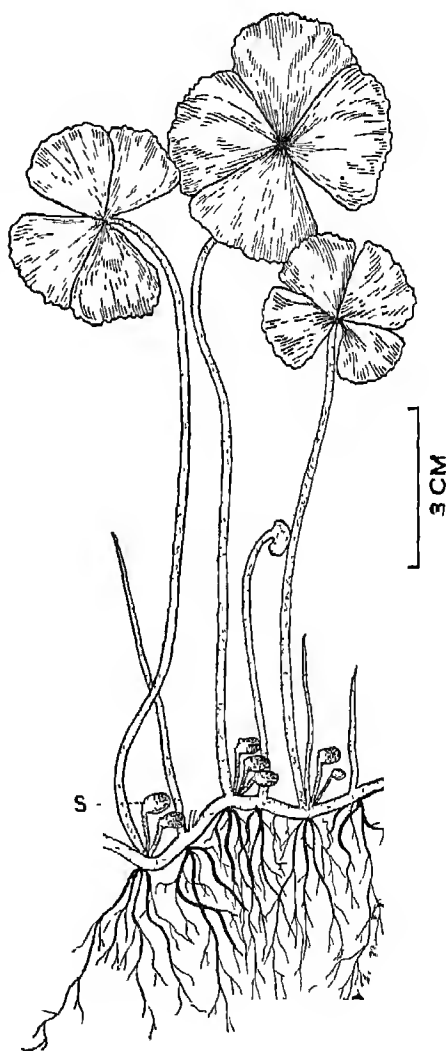


Fig 32.

Marsilea minuta, an aquatic fern with cruciform arrangement of pinnae of the leaf and reproductive sporocarps (*s*) (after Puri and Garg, Phytomorphology, 3, 1953).

lised sporocarps. *Azolla*, another member of this group, is a curious plant which is found free-floating on the surface of ponds. The small leafy branches undergo repeated multiplication and form large floating masses, like a carpet on the surface of ponds. Such masses are reddish in colour and form a striking feature of many aquatic areas in the outer ranges and along the mountainous region.



Gymnosperms

WE have so far considered the groups of plants belonging to the Thallophyta, Bryophyta and Pteridophyta which constitute the spore-bearing (Cryptogamic) plants as distinct from the seedbearing plants. Among the seed plants, two sub-divisions are recognized, the Angiosperms or the flowering plants in which the ovules and seeds develop inside a closed ovary and the Gymnosperms where the ovules are borne in an exposed position on the sporophylls. The Gymnosperms which include such well known plants like the Cycads, Ginkgo, Conifers and others were once dominant in the world's flora particularly during the Mesozoic Era. Though the conifers of the present day are widely distributed forming extensive forests in various parts of the world, the total number of species of living Gymnosperms is only a fraction of the number of Angiosperms in existence today. In the Himalaya, we have excellent forests of pines (*Pinus*), cedar (*Cedrus*), fir (*Abies*) and spruce (*Picea*); other conifers like, cypress (*Cupressus*), junipers (*Juniperus*), larch (*Larix*), yew (*Taxus*) and hemlock (*Tsuga*) are also found. In addition to the conifers, the genus, *Ephedra* is found at high altitudes. Cycads are absent.

The distribution pattern of conifers in Himalaya both in the horizontal (sectorial) as well as vertical (altitudinal) aspects deserves consideration. The Himalayan cedar, *Cedrus deodara*, is confined to the western Himalaya whereas the larch, *Larix griffithiana*, is found only from Nepal eastwards. Among the pines, the blue-pine, *Pinus griffithii* and the chir-pine, *P. roxburghii* are found throughout the range but in their vertical distribution, *P. roxburghii* is met with at altitudes up to 2000 m. and *P. griffithii* starts only at about this altitude and reaches an altitude of 3700 m. *P. gerardiana*, the chilgoza pine, which yields the edible nuts, is restricted to the inner dry localities in northwestern Himalaya. Among the spruces, *Picea smithiana* is found only in west Himalaya but the other species, *P. spinulosa* occurs in Sikkim and Bhutan. Though one of the silver firs, *Abies spectabilis* is found throughout the Himalaya, the other species, *A. pindrow* is restricted to the western sector where it occurs at altitudes much below the zone of occurrence of *A. spectabilis*. They are thus known as the high and low level firs. Species of *Juniperus* are generally found at high altitudes and those found at altitudes above 4000 m. usually present a low shrubby habit. The Himalayan cypress, *Cupressus torulosa* is found only in the outer ranges of western Himalaya. The hemlock, *Tsuga dumosa*, is another conifer with a purely eastern distribution, but the yew, *Taxus baccata* occurs throughout the range in the forests of the temperate zone.

The occurrence and distribution of the conifers are also related to the prevailing soil conditions apart from

the climatic and altitudinal considerations. For example, the chir-pine is known to prefer a quartzite base, the cedar thrives in areas rich in river borne alluvium and the Himalayan cypress is particularly seen on limestone.

Many of the Himalayan conifers, particularly *Cedrus deodara*, *Abies pindrow*, *Picea spp.*, and *Pinus griffithii* attain a big size, the trees often reaching a height of 60 m. or more with a girth of 8 to 10 m. The general habit of the conifers is very characteristic with a prominent columnar central trunk and a tiered or whorled arrangement of branches (Fig. 33, 34, 35.) Some of the juni-



Fig. 33.
Pinus roxburghii : a huge
tree growing near Askot
in eastern Kumaon.



Fig 34
Cedrus deodara, the Deodar
in western Himalaya.



Fig. 35.
Abies pindrow, the
Himalayan low-
level fir (from Kulu
Himalaya).

pers found at high altitudes, however, show a stunted, shrubby habit. All the Himalayan conifers with the solitary exception of the larch are evergreens, i.e., they do not shed their leaves at a particular time every year.

The leaves of conifers are simple and scale-like or needle-like in form. In *Cupressus torulosa*, the leaves are small, ovate and closely pressed to the branchlets. In junipers, like-wise, they are awl-shaped and closely pressed to the axis (fig. 39). In other genera they are linear, flat or grooved often with recurved margins or needle-like. In the pines, the needle-like leaves are borne in clusters of 2, 3 or 5 according to the species. Among the Himalayan pines, *P. roxburghii* and *P. gerar-*

liana have 3 needles while *P. griffithii* has 5 needles.

The conifers produce two distinct kinds of cones or strobili. Normally each cone bears only one kind of spores and most conifers are moneocious, i.e., both kinds of cones occur on the same individual (Fig. 36). The



Fig 36.

Picea smithiana with
cone-bearing branches
(m, male; f, female)

yew and some Himalayan junipers are, however, dioecious. The male cone or microsporangiate cone is very much smaller than the megasporangiate or the seed cone. In the male cone, a number of leaf like structures are aggregated, on the under surface of each one of which, the microsporangia are organised. In the pine, the male cones occur in subterminal clusters as the buds unfold at the beginning of the growing



Fig 37.

Pinus roxburghii : a
cluster of male cones

season (Fig. 37). The microsporangia have walls of one to several layers of cells and contain the microspores. The microspores or pollen of most conifers have a characteristic development of two lateral wings which are often inflated.

The megasporangiate or the seed cones are borne on short lateral branches and are conspicuous on account of their larger size. Structurally also the megasporangiate cone is different from the microsporangiate one. It consists of a central axis on which are borne a number of bracts in a spiral fashion. In the axil of each bract, a thick, woody scale is found which bears two ovules on its upper surface (Fig. 38 B,D.).

The male and the female gametophytes are developed respectively inside the pollen grain and the ovule (Fig. 38, C, E-F). The pollen grains are transferred to the ovule through the agency of wind. In the ovule, a cover or the integument encloses the nucellus in which the

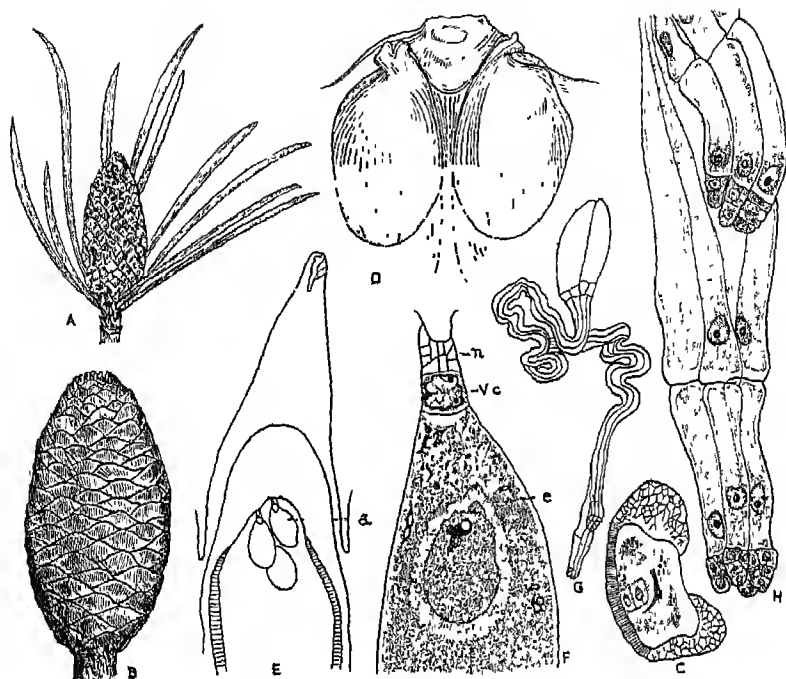


Fig. 38. A.H. Reproduction in *Cedrus deodara*; A. A male cone; B. Female cone, C Pollen grain with wings and male gametophyte inside, D. Ovules, E. Outline diagram of section of ovule with archegonia, F. An archegonium enlarged to show egg, ventral canal cell and neck cells, G. Embryos with long twisted suspensor, H. Same enlarged to show the embryonal ends (after Chaya Roy Chowdhury, 1961) (a, archegonium; n neck cells; v.c., ventral canal cell; e, egg) (A x 1, B x 1.5, C x 300, D x 30; E x 15; F x 122; G x 12; H x 100).

female gametophyte is organised. In the gametophytic tissue, a varying number of archegonia are developed. Fertilization takes place through the transference of the male nuclei through a pollen tube which enters the ovule through the micropyle. One of these male nuclei fuses with the egg of the archegonium. The interval between pollination and fertilization is a long one and may extend to several months. For example, in the Himalayan cedar, it has been recorded that pollination is effected during the months, September-October, and fertilization takes place during the later part of May of the following year, followed by the development of the embryo during June to December.

In the development of the embryo, a free-nuclear stage is followed by the formation of cells in tiers and the eventual organisation of the embryos (Fig. 38, G-H). A remarkable feature of the embryogeny in conifers is the presence of several embryos in each ovule (polyembryony). These embryos are derived either by the fertilization of more than one egg in the ovule or by the splitting of a single embryo into several linear embryos (cleavage polyembryony). The seeds which are developed from the ovules show a hard seed coat and remain pressed against the ovuliferous scales in the cone. The seeds are winged and they are released by the spreading apart of the scales. The seeds are dispersed by wind. The seed cones of most conifers are very hard, woody structures on account of the hardening of the scales and the axis in the ripe cone. The seed cones vary in their external appearance in the different genera of the

conifers. The cones may be oval to barrel-shaped or elongated, cylindrical, often brightly coloured in the growing stage. For example, the cones of *Abies* are violet-purple in colour. In junipers, however, the united scales which bear the ovules become fleshy and the ripe seeds are enclosed in a berry-like structure. In *Cupressus*, the ripe cone is globose or ellipsoid, formed of woody, shield-like scales which separate out exposing the mature seeds. In *Taxus*, the female cone is a very reduced structure and only one seed ripens. This is surrounded by a fleshy aril-like body. The male and female reproductive structures of *Taxus* are borne on different trees (dioecious).

Not only do the conifers form the most conspicuous elements in the vegetational landscape of the Himalaya but they are also of the utmost importance to the economy of the country by providing valuable timber and various other produce like wood, pulp, resin, etc. The deodar and blue-pine are among the most valuable of all timber-yielding trees of Himalaya. They are extensively used for building purposes, railway sleepers and other needs. The firs find use in general carpentry, box making, in particular, tea-chests and as match-wood. The junipers are mostly used as firewood and the aromatic species (e.g. *Juniperus wallichiana*) are burned for incense. A fragrant oil is distilled from the wood of *Cedrus*. The seeds of *Pinus gerardiana* are edible. The pines are reputed as resin-yielding trees. In the Himalaya resin is extracted both from the chir-pine and the blue-pine. It is estimated that at present 40 million kgs of resin



fig. 39. A.C. *Juniperus* A-B. *J. wallichiana*: Habit with spherical, berry-like cones (seen in B), and C. *J. communis* : Habit with spreading leaves and female cones.

are extracted annually. The resin is used in various important industries like, paper, textile, pharmaceutical, soap, varnishes and dyes. In practice, the pine trees after they have attained a certain girth are selected and incisions (blazes) are made along the periphery of the trunk. The resin which oozes out is collected in suitable containers (Fig. 40). The resin thus collected is processed in factories which are located in various places in the Himalaya.



Fig. 40.
Pinus roxburghii,
Tapping of resin.

The genus *Ephedra* is of considerable botanical interest. It is an aberrant member among the Gymnos-

perms and its relationships to the other groups are not clear. *Ephedra* is distributed mostly in the arid regions of the world. One of the species, *Ephedra gerardiana*, is found in the Himalaya at high altitudes in comparatively dry situations. It is particularly common in the dry inner valleys of northwest Himalaya, forming low, rigid bushes. In Sikkim, it may occur at higher elevations, reaching sometimes even an altitude of 4800 m. The young stem and twigs are green in colour and bear reduced scale-like leaves. The plants are dioecious. The microsporangia are found in clusters of 2 to 8 on short axes which are subtended by two small, scalelike

structures. Such male cones may be solitary or fascicled on the erect, stiff branches of the shoots (Fig. 41).



Fig. 41

Ephedra gerardiana a clump of male shoots bearing fascicled clusters of male cones.

In the female cone the short axis bears one or two naked ovules in the axil of bracts. After fertilization, the bracts become fleshy and assume a red colour. They enclose one or two seeds



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